Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Simulation of power maneuvering experiment of MASLWR test facility by MARS-KS code

Ju Yeop Park*
Korea Institute of Nuclear Safety, Operating Reactor Regulation Division, 19 Guseong-dong Yuseong-gu, Daejeon 305-338, KOREA
**Corresponding author: k385pjy@kins.re.kr*

1. Introduction

Since 2009, IAEA has conducted a research program entitled as ICSP (International Collaborative Standard Problem) on integral PWR design to evaluate current the state of the art of thermal-hydraulic code in simulating natural circulation flow within integral type reactor. In this ICSP, experimental data obtained from MASLWR (Multi-Application Small Light Water Reactor) [1] test facility located at Oregon state university in the US have been simulated by various thermal-hydraulic codes of each participant of the ICSP and compared among others. MASLWR test facility is a mock-up of a passive integral type reactor equipped with helical coil steam generator. Since SMART reactor which is currently being developed in Korea also adopts a helical coil steam generator, Korea Institute of Nuclear Safety (KINS) has joined this ICSP to assess the applicability of a domestic regulatory audit thermal-hydraulic code (i.e. MARS-KS code) for the SMART reactor including wall-to-fluid heat transfer model modification [2] based on independent international experiment data. In the ICSP, two types of transient experiments have been focused and they are 1) loss of feedwater transient with subsequent ADS operation and long term cooling (SP-2) and 2) normal operating conditions at different power levels (SP-3). In the present study, KINS simulation result by the MARS-KS code (KS-002 version) for the SP-3 experiment is presented in detail and conclusion on MARS-KS code performance drawn through this simulation is described.

2. Test facility description and its nodalization

MASLWR test facility comprises core, chimney, downcomer, PZR (Pressurizer), RPV (Reactor Pressure Vessel), HPC (High Pressure Containment), CPV (Containment Pool Vessel), HTP (Heat Transfer Plate), ADS (Automatic Depressurization System), SG (Steam Generator) and FWS (Feedwater System). In normal operation, coolant flows up within a chimney inside of the RPV by buoyancy force developed at the core which is located in bottom part of the chimney and then the coolant exchanges heat with the helical coil SG. After that, the coolant flows down through the downcomer and returns to the core again. In emergency operation, ADS operates and it relieves pressure build-up within the RPV by venting high pressure and high temperature steam to HPC. Steam delivered to the HPC is condensed on the HTP which transfers heat from the HPC to the CPV through condensation heat transfer. The CPV works as a final heat sink when any accident happens.

For the SP-3 experiment, core power level was increased stepwise manner from initial 40kW to 320kW. And the feedwater flowrate and steam outlet pressure were modulated to maintain steady state at each core power levels. Therefore, measured data of core power, feedwater flowrate and steam outlet pressure including the RPV injection flow during the SP-3 experiment are used as boundary conditions in the MARS-KS code simulation. Nodalization for simulation of the SP-3 experiment is shown in Fig. 1. In this nodalization, multiple helical coil tubes of the SG are modeled as one lumped pipe. As for heat structures, in addition to the core, the SG and the HTP, pressurizer heaters and the RPV are included in heat structures modeling because measured experimental data showed heat losses to atmosphere was comparable at low power levels. Since the ADS does not work at all during the experiment, the ADS, the HPC and the CPV are omitted in the nodalization. Helical coil specific wall-to-fluid heat transfer model of the MARS-KS code is used, surface roughness of 3.0E-5m and heat structure material of stainless steel are uniformly employed. In developing this nodalization, SNAP tool (version 2.0.7, August 15, 2011) developed by the US NRC was used.

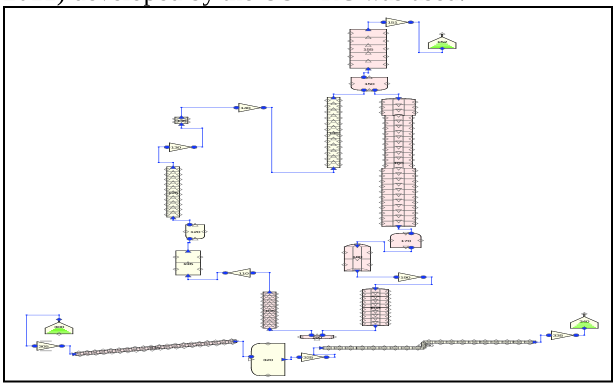

Fig. 1. Nodalization for MASLWR Test Facility.

3. Results of the MARS-KS code simulation

3.1 Steady state

Since the SP-3 experiment is triggered from a steady state of which core power is 40kW by increasing core power stepwise manner, a steady state simulation at core power 40kW was performed first to establish initial condition of the SP-3 experiment. In this steady state simulation, form loss coefficients within the RPV which were mostly determined with reference to CRANE handbook [3] were further tuned with respect to the steady state primary mass flowrate of the SP-3 experiment. Furthermore, external heat transfer coefficient at the RPV outward surface was estimated by matching the initial steady state data, too. Resulting steady state calculation results are compared with experimental data in Table 1.

Table 1. Steady state comparison of the SP-3

Parameter	MASLWR	UNIT	EXP	CALC
Pressurizer pressure	PT-301	MPa(a)	8.718	8.718(BC)
Pressurizer level	LDP-301	m	0.3574	0.3541
Power to core heater rods	KW-101/102	kW	40	40(BC)

Feedwater temperature	TF-501	℃	31.5	31.5(BC)
Steam temperature	Avg. of TF-611 to TF-634	℃	256.4	262.9
Steam pressure	FVM-602-P	MPa(a)	1.446	1.446(BC)
Primary flow at core outlet	FDP-131	kg/s	0.68	0.69
Primary coolant temperature at core inlet	TF- 121/122/ 123/124	℃	250.3	251.7
Primary coolant temperature at core outlet	TF-106	℃	262.8	263.5
Feedwater flow	FMM-501	kg/s	0.0100	0.0101
Steam flow	FVM-602-M	kg/s	0.0100	0.0101

As can be shown the table, almost all variables calculated agree reasonably with the experimental data in spite of some discrepancy in steam temperature. Especially, core inlet and outlet temperatures predicted by the code show good agreement with the experimental data. The primary mass flowrate also show good agreement.

3.2 Transient state

With the initial conditions established by the steady state run, transient simulation of the SP-3 experiment was performed by using measured stepwise core power, feedwater flowrate and steam outlet pressure as boundary conditions. Comparison between measured values and modeled ones for the stepwise core power, the feedwater flowrate and steam outlet pressure which were employed in the SP-3 simulation are shown in Fig. 2, 3 and 4. Except the steam outlet pressure, modeled boundary conditions almost match well with experimental data.

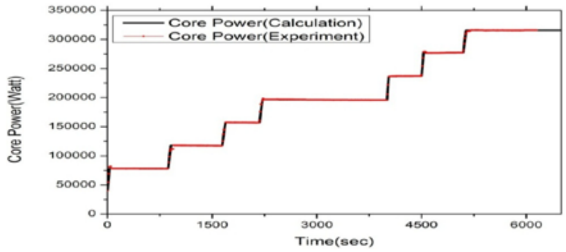

Fig. 2. Comparison of stepwise core power.

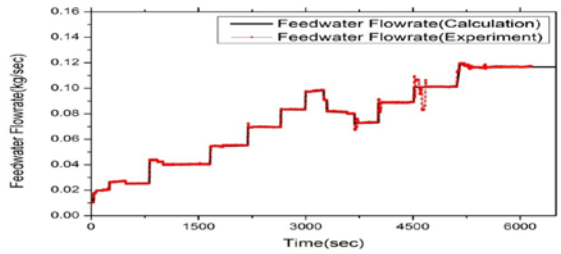

Fig. 3. Comparison of feedwater flowrate.

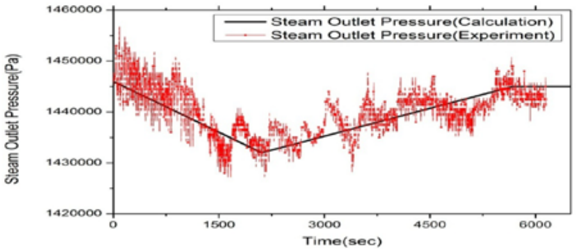

Fig. 4. Comparison of steam outlet pressure.

Figure 5 shows steam temperature at the SG outlet. Agreement between the code calculation and the experimental data is good. Pressure differences at various locations within the RPV are shown in Fig. 6. Overall trends of pressure differences calculated are well compatible with experimental data. However, the primary mass flowrate shows some discrepancy. (Fig. 7) The exact reason of this discrepancy is not clear. Figure 8 shows core inlet/outlet temperatures comparison between the calculation and the experimental data. As can be shown the figure, agreement between the calculation and the experiment is reasonable.

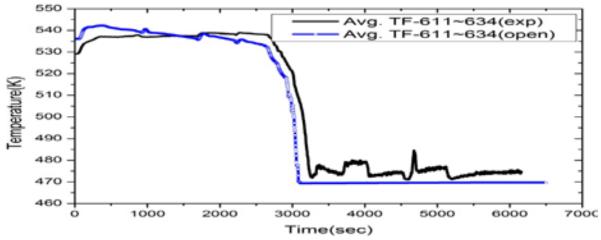

Fig. 5. Comparison of steam outlet temperature.

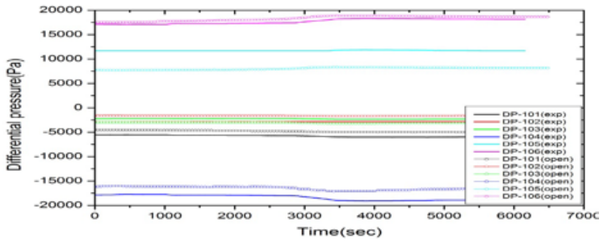

Fig. 6. Comparison of differential pressures.

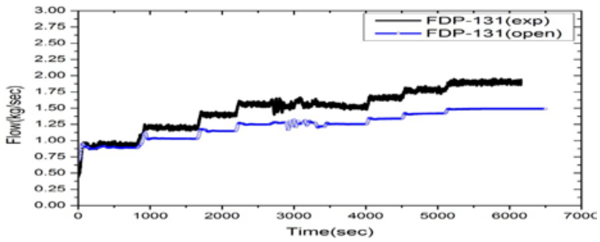

Fig. 7. Comparison of primary mass flowrate.

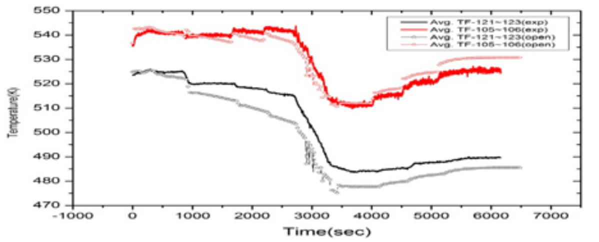

Fig. 8. Comparison of fluid temperatures in the HPC.

4. Conclusion

Performance of the MARS-KS code is evaluated through the simulation of the power maneuvering experiment of the MASLWR test facility. Steady run shows the helical coil specific heat transfer model of the code is reasonable. However, identified discrepancy of the primary mass flowrate at transient run shows code performance for pressure drop needs to be improved considering sensitivity of the flowrate to the pressure drop at natural circulation.

REFERENCES

[1] Galvin, M. R. and Bower, C. J., OSU MASLWR Test Facility Modification Description Report, OSU-MASLWR-07002, 2010.

[2] KINS, KINS/HR-627, Development of Auditing Technology for Accident Analysis of SMART-P, 2004.

[3] CRANE Co, Flow of Fluids through valves, fittings and pipe, Technical Paper No. 410, 2009.